INTEGRATED DESIGN APPROACH FOR PV HYBRID SYSTEMS

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Supplying electricity to remote or rural areas is often more economical with decentralized generation than with grid extensions, especially when there is a relatively low consumption density. Examples are both technical applications like cell phone networks or village power supplies. Particularly if the average solar irradiation varies strongly throughout the year, hybrid systems e.g. consisting of a PV generator, a diesel gensets as backup and a battery storage are often used to reliably and cost-effectively provide electricity in autonomous systems. In the future, seasonal electricity storage using hydrogen might become a viable alternative to maintenance intensive backup generators. In any case, the most important design criteria for hybrid systems are their life cycle cost. As components with complex ageing characteristics and significant maintenance or replacement cost are involved, it is not sufficient to design systems in respect to minimum investment cost.

In order to assess the technological potential of seasonal hydrogen storage in autonomous systems while taking life cycle behaviour into account, the EU-funded project FIRST (Fuel cell Innovative Remote System for Telecom)[1] evaluated and developed a power supply system for telecommunication repeater stations. The average load of the repeater is 150W. An integrated approach to design, optimization, development and field testing of autonomous systems has been used. It is described and technical results of the specific system are reported.

The system design approach: <u>Data collection</u>: At the beginning, cruical data for the system and its environment is collected. E.g. it is necessary to know the load profile, the range of allowable component sizes and their differential cost (i.e. €/W) as well as interest rates and labour cost for installation, repair and maintenance. Fuel prices (e.g. hydrogen, diesel) and individual requirements (e.g. solar fraction of power supply, reliability, operation conditions) complement the system description. Meteorological records for the desired location for up to 20 years are used in order to include enough statistical bandwidth.

<u>Technical and Least Cost Optimization (TALCO):</u> An algorithm set based on genetic principles searches then for the optimum solution respecting the defined boundary conditions. A server farm is used to parallelize the many thousands simulations which are necessary. The first result is the system configuration and operation strategy which causes the least lifetime cost over a predefined period (e.g. 20 years). Hidden costs which are often neglected in a short term view such as maintenance and replacement of aging components (e.g. batteries) are considered in the calculation. Besides the absolute cost for operating the power supply system, a sensitivity analysis can be carried out in order to learn more about the effects of parameter variation (e.g. fuel prices, PV module orientation, battery size). The second result are parameters for the system operation such as conditions for using external generators (like fuel cell start and stop at certain levels of battery state-of-charge). Thirdly the requirements for some components are defined e.g. by their pre-calculated operation time. These lead to more detailed specifications for the component sourcing.

<u>Battery related algorithms:</u> The lead acid battery plays an important role in any off-grid power system as it is both a major cost factor as well as it is the insurance for uninterrupted supply throughout shortages of irradiation or wind. To ensure optimum operation of this component, various algorithms have been developed basing entirely on quantities which can be aquired non-intrusively (i.e. voltage, current, temperature). They give information on the state-of-charge (SOC), the actual available capacity as state-of-health (SOH) and control the charging process. Putting all together, the lifetime of the component can be extended. The exact timing for involving expensive backup generators such as fuel cells and gensets can be determined. Also a prediction of component failure is possible which is very interesting for high-availability supplies or setting up maintainance plans for a larger numbers of systems that are dispersed over a certain area.

<u>Operation Platform and Operation</u>: The data from optimization (i.e. component sizing, thresholds for component utilization) and the battery related algorithms are integrated onto a computer platform together with a specifically designed robust and reliable operation system. It ensures an operation of the system as closely as possible to the pre-calculated strategy from TALCO, thus leading to the most cost effective operation the same way. Depending on the system size the platform can be as small as a low-power microcontroller. The implementation of personal computer hardware is feasible in large systems such as mountain huts. By means of communication systems remote access is possible. Economical operation is furthermore supported by preview and schedule of maintenance tasks (i.e. refuelling). Reliability is improved by detection of deviations and defects.

The advantages of this integral approach: it is universal, all configurations are feasible, no „surprises“ during operation due to 20 years of simulation occur, direct link to the realized control strategy is established.

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Explanatory page:

Realization example: FIRST Project (http://www.inta.es/first)
A consortium formed by industrial and research parties from four countries (Spain, Germany, France and Italy), led and co-ordinated by a telecommunication company (the end user), are working together in the FIRST project (Fuel cell Innovative Remote System for Telecom). The goal of the project is to demonstrate how a reliable power supply for repeater stations in rural areas can be realized in the future even for small loads. This is achieved by using state of the art hydrogen technology and the integrated design approach as described. The system is capable of powering a load of some 150 watts continuously (3.6 kWh/day). Normally energy is produced by the PV generator and the surplus is stored in the battery (see Fig. 1 for a system overview). PV-battery systems are fine for areas near the equator, where only small seasonal deviation in daylength and predictable weather conditions exist. In any other case even huge component sizes can not avoid massive surplus (wasted energy) in summer and shortages in winter. In the FIRST project the energy balance is realized via a hydrogen cycle: The electrolyzer produces hydrogen in long sunny periods which is stored in a metal-hydride system. In case of energy shortage the hydrogen is used up by the fuel cell and reloads the battery. The control of fuel cell, storage and electrolyzer as well as for charging controller and load is done by the Energy Management System. After a design and development phase of two years, the showcases have been commissioned and are currently operating on test sites. Deployment of this project is foreseen for many applications in the telecom industry.

The integrated design approach comprising data collection, simulation and optimization, the implementation in hardware and the operation has been shown. The example from the project FIRST has been choosen, as all the steps have been used here. The advantages are the flexibility towards system configuration and size. In future standardization of components and introduction of intelligent interfaces might lead to cost effictive and highly reliable power supplies for off-grid applications. Then an integrated design process will become crucial. The base for such developments has been outlined here.

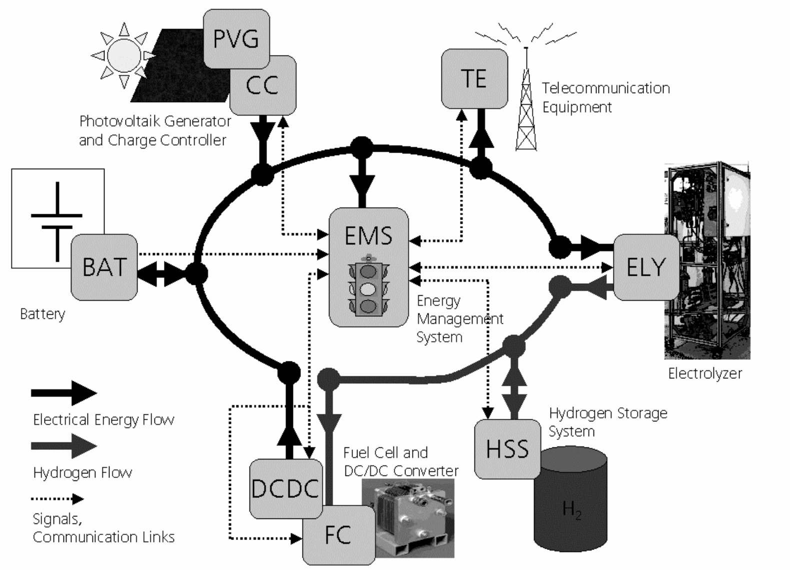

Fig. 1 System overview of the realized FIRST prototype